



Docket: 740756-2670
Serial No. 10/713,219
PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:

Shinji MAEKAWA et al.

Application No. 10/713,219

Filed: November 17, 2003

For: METHOD FOR FABRICATING THIN
FILM TRANSISTOR



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Group Art Unit: 2813

Examiner: Laura M. Shillinger

Confirmation No. 2735

Date: October 25, 2007

**TRANSMITTAL OF VERIFIED ENGLISH
TRANSLATION OF PRIORITY DOCUMENT**

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Filed concurrently herewith the Amendment submitted on October 25, 2007, is an English Translation of Japanese Priority Document No. 2002-340167 with Declaration. Consideration is respectfully requested.

Acknowledgment is respectfully requested.

Respectfully submitted,

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) Examiner: Schillinger, Laura M

) Group Art Unit: 2813

VERIFICATION OF TRANSLATION

Commissioner for Patents

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Sir:

I, Mika Tatsumi, C/O Semiconductor Energy Laboratory Co., Ltd. 398, Hase, Atsugi-shi, Kanagawa-ken 243-0036 Japan, a translator, herewith declare:

that I am well acquainted with both the Japanese and English Languages;

that I am the translator of the attached English translation of the Japanese Patent Application No. 2002-340167 filed on November 22, 2002; and

that to the best of my knowledge and belief the following is a true and correct English translation of the Japanese Patent Application No. 2002-340167 filed on November 22, 2002.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Date: this 16th day of October 2007

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Name: Mika Tatsumi



[Name of Document] Patent Application

[Reference Number] P006749

[Filing Date] November 22, 2002

[Attention] Commissioner, Patent Office

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[Indication of Handlings]

[Number of Prepayment Note] 002543

20

[Payment Amount] 21000

[List of Attachment]

[Attachment] Specification 1

[Attachment] Drawing 1

[Attachment] Abstract 1

25

[Proof] required

[Document Name] Specification

[Title of the Invention] METHOD FOR FABRICATING THIN FILM TRANSISTOR

[Scope of Claims]

[Claim 1]

- 5 A method for fabricating a thin film transistor, comprising:
- forming a first amorphous silicon film;
 - forming a material including a metal element to promote crystallization of silicon over the first amorphous silicon film;
 - forming a first crystalline silicon film by heating the first amorphous silicon
 - 10 film;
 - forming a second amorphous semiconductor film over the first amorphous silicon film;
 - heating the first crystalline silicon film and the second amorphous semiconductor film; and
 - 15 removing the second amorphous semiconductor film;
 - characterized in that the second amorphous semiconductor film contains a nitrogen concentration of 1×10^{18} atoms/cm³ or lower, an oxygen concentration of 8×10^{19} atoms/cm³ or lower, and a noble gas concentration of 1×10^{20} atoms/cm³ or higher.

[Claim 2]

- 20 A method for fabricating a thin film transistor, comprising:
- forming a first amorphous silicon film;
 - forming a material including a metal element to promote crystallization of silicon over the first amorphous silicon film;
 - forming a first crystalline silicon film by heating the first amorphous silicon
 - 25 film;

irradiating the first crystalline silicon film with a laser beam;

forming a second amorphous semiconductor film over the first amorphous silicon film;

5 heating the first crystalline silicon film and the second amorphous semiconductor film; and

removing the second amorphous semiconductor film;

characterized in that the amorphous semiconductor film contains a nitrogen concentration of 1×10^{18} atoms/cm³ or lower, an oxygen concentration of 8×10^{19} atoms/cm³ or lower, and a noble gas concentration of 1×10^{20} atoms/cm³ or higher.

10 [Claim 3]

A method for fabricating a thin film transistor, comprising:

forming a first amorphous silicon film;

forming a material including a metal element to promote crystallization of silicon over the first amorphous silicon film;

15 forming a second amorphous semiconductor film over the first amorphous silicon film;

heating the first crystalline silicon film and the second amorphous semiconductor film; and

removing the second amorphous semiconductor film;

20 characterized in that the second amorphous semiconductor film contains a nitrogen concentration of 1×10^{18} atoms/cm³ or lower, an oxygen concentration of 8×10^{19} atoms/cm³ or lower, and a noble gas concentration of 1×10^{20} atoms/cm³ or higher.

[Claim 4]

A method for fabricating a thin film transistor, comprising:

forming a first amorphous silicon film;

forming a material including a metal element to promote crystallization of silicon over the first amorphous silicon film;

5 forming a first crystalline silicon film by heating the first amorphous silicon film;

forming a second amorphous semiconductor film over the first amorphous silicon film;

moving the metal element into the second amorphous semiconductor film by heating the first crystalline silicon film and the second amorphous semiconductor film;

10 and

removing the second amorphous semiconductor film;

characterized in that the second amorphous semiconductor film contains a nitrogen concentration of 1×10^{18} atoms/cm³ or lower, an oxygen concentration of 8×10^{19} atoms/cm³ or lower, and a noble gas concentration of 1×10^{20} atoms/cm³ or higher.

15 [Claim 5]

A method for fabricating a thin film transistor, comprising:

forming a first amorphous silicon film;

forming a material including a metal element to promote crystallization of silicon over the first amorphous silicon film;

20 forming a first crystalline silicon film by heating the first amorphous silicon film;

forming a second amorphous semiconductor film over the first amorphous silicon film;

performing gettering by heating the first crystalline silicon film and the second

amorphous semiconductor film; and

removing the second amorphous semiconductor film;

characterized in that the amorphous semiconductor film contains a nitrogen concentration of 1×10^{18} atoms/cm³ or lower, an oxygen concentration of 8×10^{19}

5 atoms/cm³ or lower, and a noble gas concentration of 1×10^{20} atoms/cm³ or higher.

[Claim 6]

A method for fabricating a thin film transistor, comprising:

forming a first amorphous silicon film;

forming a material including a metal element to promote crystallization of

10 silicon over the first amorphous silicon film;

forming a first crystalline silicon film by heating the first amorphous silicon film;

forming a barrier film over the first crystalline silicon film;

forming a second amorphous semiconductor film over the barrier film;

15 heating the first crystalline silicon film and the second amorphous semiconductor film; and

removing the second amorphous semiconductor film and the barrier film;

characterized in that the second amorphous semiconductor film contains a nitrogen concentration of 1×10^{18} atoms/cm³ or lower, an oxygen concentration of $8 \times$

20 10^{19} atoms/cm³ or lower, and a noble gas concentration of 1×10^{20} atoms/cm³ or higher.

[Claim 7]

A method for fabricating a thin film transistor according to Claim 6, characterized in that the barrier film is an oxide film made by using ozone water or a hydrogen peroxide solution of sulfuric acid, hydrochloric acid or nitric acid.

[Claim 8]

A method for fabricating a thin film transistor according to any one of claims 1 to 7, characterized in that the second amorphous semiconductor film is formed by sputtering.

5 [Claim 9]

A method for fabricating a thin film transistor, comprising:

forming a first amorphous silicon film;

forming a material including a metal element to promote crystallization of silicon over the first amorphous silicon film;

10 forming a first crystalline silicon film by heating the first amorphous silicon film;

forming a second amorphous semiconductor film over the first amorphous silicon film;

15 heating the first crystalline silicon film and the second amorphous semiconductor film; and

removing the second amorphous semiconductor film;

characterized in that the second amorphous semiconductor film is formed by sputtering in a state in which a flammable gas and a noble gas are supplied to a film formation chamber, an oxygen concentration in the film formation chamber is reduced, 20 and the supply of the flammable gas is stopped; and the second amorphous semiconductor film contains a nitrogen concentration of 1×10^{18} atoms/cm³ or lower, an oxygen concentration of 8×10^{19} atoms/cm³ or lower, and a noble gas concentration of 1×10^{20} atoms/cm³ or higher.

[Claim 10]

A method for fabricating a thin film transistor according to Claim 9, characterized in that the flammable gas is one element or more elements selected from a group consisting of SiH_4 , Si_2H_6 , SiH_2Cl_2 , SiHCl_3 , SiCl_4 , GeH_4 , PH_3 , B_2H_6 , AsH_3 , and H_2Se .

5 [Claim 11]

A method for fabricating a thin film transistor, comprising:

forming a first amorphous silicon film;

forming a material including a metal element to promote crystallization of silicon over the first amorphous silicon film;

10 forming a first crystalline silicon film by heating the first amorphous silicon film;

forming a second amorphous semiconductor film over the first amorphous silicon film;

15 heating the first crystalline silicon film and the second amorphous semiconductor film; and

removing the second amorphous semiconductor film;

characterized in that the second amorphous semiconductor film is formed by sputtering in a state in which a filament including Ti that is disposed in a film formation chamber is heated, an oxygen concentration in the film formation chamber is reduced, 20 and the heating of the filament is stopped; and the second amorphous semiconductor film contains a nitrogen concentration of 1×10^{18} atoms/cm³ or lower, an oxygen concentration of 8×10^{19} atoms/cm³ or lower, and a noble gas concentration of 1×10^{20} atoms/cm³ or higher.

[Claim 12]

A method for fabricating a thin film transistor, comprising:

forming a first amorphous silicon film;

forming a material including a metal element to promote crystallization of silicon over the first amorphous silicon film;

5 forming a first crystalline silicon film by heating the first amorphous silicon film;

forming a second amorphous semiconductor film over the first amorphous silicon film;

10 heating the first crystalline silicon film and the second amorphous semiconductor film; and

removing the second amorphous semiconductor film;

characterized in that the second amorphous semiconductor film is formed by sputtering in a state in which a voltage is applied between electrodes including Ti disposed in a film formation chamber to generate a plasma, an oxygen concentration in the film formation chamber is reduced, and applying the voltage between the electrodes is stopped; and the second amorphous semiconductor film contains a nitrogen concentration of 1×10^{18} atoms/cm³ or lower, an oxygen concentration of 8×10^{19} atoms/cm³ or lower, and a noble gas concentration of 1×10^{20} atoms/cm³ or higher.

[Claim 13]

20 A method for fabricating a thin film transistor according to any one of claims 1 to 12, characterized in that the second amorphous semiconductor film is removed by wet etching using hydrazine or tetraethyl ammonium hydroxide.

[Claim 14]

A method for fabricating a thin film transistor according to any one of claims 1

to 13, characterized in that the noble gas element is one element or more elements selected from a group consisting of: helium, neon, argon, krypton, and xenon.

[Claim 15]

5 A method for fabricating a thin film transistor according to any one of claims 1 to 14, characterized in that the metal element is one element or more elements selected from a group consisting of iron, nickel, cobalt, ruthenium, rhodium, palladium, osmium, iridium, platinum, copper, and gold.

[Detailed Description of the Invention]

[0001]

10 [Technical Field of the Invention]

The present invention relates to a thin film transistor and a fabricating method thereof, further, a semiconductor device including the thin film transistor and a manufacturing method thereof.

[0002]

15 [Conventional Art]

In recent years, researches on high performance semiconductor devices (specifically, liquid crystal display devices, EL display devices and other display devices) using a thin film transistor have been promoted. A thin film transistor (hereinafter, referred to as a TFT) having high mobility needs to be realized particularly
20 for a semiconductor device which is required to have high-speed performance and increased functionality. As a method for improving the crystallinity of the semiconductor film, a metal element, as typified by a nickel element (Ni), which promotes crystallization of an amorphous silicon film (hereinafter, simply referred to as a metal element) is added into the semiconductor film, formed into a film, or applied

thereto (all of which are referred to as forming a substance having a metal element), and then, it is heated and a crystallization process for forming a crystalline semiconductor film is performed.

[0003]

5 In the crystallization process described above, a crystalline semiconductor film with large-size particles can be obtained by using a metal element typified by Ni to promote crystallization. In addition, the crystalline semiconductor film in which grain boundaries are connected with each other at high ratio and grain defects are less is obtained.

10 [0004]

However, a metal element typified by Ni has an adverse effect on device properties (electric properties) of a TFT, and therefore, a step for removing the elements (hereinafter referred to as a gettering) is carried out. A gettering is known as a technique for segregating metal impurities brought in a semiconductor to a gettering site
15 (or it is also called a gettering sink) with some kind of energy, thereby reducing impurity concentrations in an active region of an element.

[0005]

Gettering processes are divided broadly into two categories, an extrinsic gettering and an intrinsic gettering. The extrinsic gettering provides a gettering effect
20 by applying a strain field or chemical action from the exterior. Meanwhile, the intrinsic gettering utilizes a strain field of a lattice defect caused by oxygen that is generated inside a single crystal silicon wafer.

[0006]

As a specific example of gettering processes, a gettering is performed by

forming a region added with a noble gas element (noble gas) or a semiconductor film added with a noble gas element and moving a metal element therein by heat treatment. Thereafter is removed the region doped with the noble gas element (noble gas) or the semiconductor film doped with the noble gas element (for example, see Patent Document 1).

[0007]

[Patent Document 1]

Japanese Patent Laid-Open No. 2002-313811

[0008]

10 [Problems to be solved by the Invention]

However, when a gettering sink is removed by gettering according to the above-described method, the gettering sink could not be etched rightly in some cases. That is, even when a gettering sink is removed by using an alkaline solution of etchant having a high selectivity to the gettering sink and a barrier film functioning as an etching stopper, residue of the gettering sink is left.

[0009]

A TFT having such residue of a gettering sink has a negative characteristic such as Ioff defect and low reliability. Further, defects generate in a mass-production line due to the gettering residue, and thus, the yield ratio decreases.

20

[0010]

It is an object of the present invention to provide a method for fabricating a TFT in which a gettering sink can be removed without leaving residue in a process for crystallizing a semiconductor film by using a metal element. Further, it is another object of the present invention to provide a semiconductor device provided with a TFT

formed according to the present invention.

[0011]

[Means for solving the problem]

In order to achieve the above-described objects, the present inventors focus on
5 impurities of a semiconductor film that serves as a gettering sink. A characteristic is
that the semiconductor film has a nitrogen (N_2) concentration of 1×10^{18} atoms/cm³ or
lower, an oxygen (O_2) concentration of 8×10^{19} atoms/cm³ or lower. Further, a
characteristic is that the semiconductor film has a noble gas concentration of 1×10^{20}
atoms/cm³ or higher so that the semiconductor film as a gettering sink can achieve a
10 desired gettering function. As the noble gas element, one or more elements selected
from the group consisting of helium (He), neon (Ne), argon (Ar), krypton (Kr), and
xenon (Xe) is/are used.

[0012]

In order to achieve the above-described concentrations of the impurities, the
15 present invention is characterized that oxygen that is an impurity in a chamber is
reduced by using a flammable gas for burning and exhausting oxygen. As this
flammable gas, a gas including any one selected from the group consisting of: SiH_4 ,
 Si_2H_6 , SiH_2Cl_2 , $SiHCl_3$, $SiCl_4$, GeH_4 , PH_3 , B_2H_6 , AsH_3 , and H_2Se can be used.

[0013]

20 Further, in order to achieve the above-described concentrations of the
impurities, the present invention is characterized in that an electrode including Ti is
used, and a voltage is applied to the electrode to generate plasma, at the same time,
oxygen that is the impurity in a chamber is reduced by exhausting. Alternatively, a
filament including Ti is disposed in a chamber (film formation chamber) and the oxygen

in the chamber may be reduced by exhausting, while the filament is being heated.

[0014]

A characteristic is that a semiconductor film that serves as a gettering sink is formed by high frequency sputtering method in the chamber in which the pretreatment to reduce the impurity concentrations as described above has been conducted. When the semiconductor film that serves as a gettering sink is formed, a noble gas element is added to the semiconductor film that serves as a gettering sink by an ion implantation method or an ion doping method, or the noble gas element is assimilated when the semiconductor film that serves as a gettering sink is formed.

[0015]

For a heat treatment for gettering, LRTA (Lamp Rapid Thermal Anneal) method which is performed by radiation of one or more lamps selected from the group consisting of: a halogen lamp, a metal halide lamp, a xenon arc lamp, a carbon arc lamp, a high pressure sodium lamp, and a high pressure mercury lamp; GRTA method which is performed by using an inert gas such as nitrogen or argon as a heating medium; or a furnace annealing method which is performed by using an electric heating furnace may be adopted. This heat treatment allows a metal element to diffuse and move into the semiconductor film that serves a gettering sink.

[0016]

Note that one or more elements selected from the group consisting of iron (Fe), nickel (Ni), cobalt (Co), ruthenium (Ru), rhodium (Rh), palladium (Pd), osmium (Os), iridium (Ir), platinum (Pt), copper (Cu), and gold (Au) is/are used for a metal element.

[0017]

Subsequently, the semiconductor film that is a gettering sink is removed

appropriately by etching. As an etching method, a wet etching method that is performed by using an alkaline solution typified by hydrazine or tetraethyl ammonium hydroxide (TMAH, chemical formula: $(\text{CH}_3)_4\text{NOH}$) is employed.

[0018]

5 At this time, preferably, a barrier film serving as an etching stopper is formed at an interface between a semiconductor film that is an active layer of a TFT and the semiconductor film that is a gettering sink. Then, the barrier film is removed by using hydrofluoric acid. As the barrier film, a thin oxide film (chemical oxide) that is processed by ozone water, or a solution in which sulfuric acid, hydrochloric acid, or
10 nitric acid is mixed with hydrogen peroxide solution can be used. Alternatively, a plasma treatment in an oxygen atmosphere may be performed, or an ultraviolet irradiation in an atmosphere containing oxygen may be performed to generate ozone for oxidation treatment. Alternatively, a thin oxide film may be formed by being heated at temperatures from about 200 °C to 350 °C using a clean oven or an oxide film of from 1
15 to 5 nm thick may be formed by a plasma CVD method, a sputtering method, or a vapor deposition method.

[0019]

According to the present invention, a pretreatment for reducing impurity concentrations is performed in a chamber in which a semiconductor film that serves as a
20 gettering sink is formed. As a result, the impurity concentrations of the semiconductor film that serves as a gettering sink are reduced, and thus, etch residue can be reduced. Accordingly, less etch residue is left, as compared with a method for fabricating a TFT formed by using a semiconductor film that serves as a gettering sink, made according to a conventional method, and therefore, the yield ratio in fabricating a semiconductor

device having a TFT can be enhanced.

[0020]

[Embodiment Modes of the Invention]

Hereinafter, the embodiment modes of the present invention are described with
5 reference to figures. Note that, in all figures for describing the embodiment modes, the
same reference numbers are used for the same portions or portions that have a similar
function. Repetitive descriptions thereof are omitted.

[0021]

(Embodiment Mode 1)

10 In this embodiment mode, an example of forming a semiconductor film that
serves as a gettering sink in a chamber of which impurity concentration is reduced by
using a flammable gas is described with reference to Fig. 1.

[0022]

Fig. 1 shows a sputtering apparatus for forming a semiconductor film that
15 serves as a gettering sink. The sputtering apparatus includes a film formation chamber
100, a substrate holder 101, a magnetic material (magnet) 102, a substrate holding
means 103 in the upper portion of the film formation chamber, a first gas supply means
131 for supplying SiH_4 that is an example of flammable gases, and a second gas supply
means 132 for supplying argon (Ar) that is an example of noble gases. In addition, a
20 third gas supply means 133 for supplying hydrogen (H_2) may be provided. This
hydrogen gas can make the degree of mixing a flammable gas and a noble gas high, and
thus, the gases can be supplied smoothly.

[0023]

On the side opposite to the substrate holder 101, a target 104 is provided and an

electric power is supplied from a high frequency power supply 106. A target lifting means 107 (that can carry up and down the target) having a function of controlling the distance between the target and the substrate is provided. A permanent magnet 105 for applying electric field to the target and a coolant 108 for cooling the target are provided in the vicinity of the target. A current plate 109 for controlling the gas flow is provided and an exhausting means such as a pump is provided via a conductance valve 120. The exhausting means includes a turbo pump 121 that is a first pump and a rotary pump or a dry pump 122 that is a second pump. Thereafter, the gases are exhausted separately through a first exhausting system 134 and a second exhausting system 135. They are separated into the first exhausting system and the second exhausting system so as to prevent the flammable gas and the reactive gas from reacting with each other.

[0024]

Further, the sputtering apparatus is preferably connected to a plasma CVD apparatus or the like via a transferring gate 136 in order to be used as a multi-chamber.

15 [0025]

Next, a method for fabricating a semiconductor film that serves as a gettering sink by using the sputtering apparatus shown in Fig. 1 is described below.

[0026]

A substrate is held in the substrate holder 101, and then the substrate 140 is installed in the substrate holding means 103. In this embodiment mode, a case is described where a pretreatment is performed while the substrate is set in the substrate holding means 103. However, the arrangement of the substrate is not limited to this.

[0027]

The pretreatment for reducing the impurity concentration in the film formation

chamber is as follows; monosilane (SiH_4) gas that is a flammable gas and argon (Ar) that is a noble gas through the first gas supply means 131 and the second gas supply means 132 are supplied into the film formation chamber 100 respectively. And hydrogen (H_2) gas is, preferably, supplied into the film formation chamber 100 through the third gas supply means 133. At this time, the flow rate of the gas at this time is set to approximately 200 sccm.

[0028]

In place of monosilane, a gas including any one selected from the group consisting of Si_2H_6 , SiH_2Cl_2 , SiHCl_3 , SiCl_4 , GeH_4 , PH_3 , B_2H_6 , AsH_3 and H_2Se may be supplied. Further, in place of argon, a gas including any element selected from the group consisting of helium, neon, krypton, and xenon may be supplied.

[0029]

Subsequently, the inside of the film formation chamber is exhausted through the turbo pump 121 and the rotary pump 122. Note that, a dry pump may be used instead of the rotary pump. As a result, an impurity element (specifically, oxygen) in the film formation chamber is exhausted together with monosilane gas that is a flammable gas to the outside of the film formation chamber. The pressure of the film formation chamber is set to approximately 1 Torr (133 Pa).

[0030]

In this state, the pretreatment for the sputtering apparatus is performed for about 5 to 10 minutes. As a result, the oxygen concentration in the film formation chamber can be reduced. Note that, the substrate 140 set in the substrate holder 101 is preferably heated at temperatures from about 100°C to 200°C . Of course, the pretreatment may be performed by supplying the gases even in the state in which the

substrate is not set in the substrate holder 101.

[0031]

In this manner, the impurity concentration (specifically, oxygen concentration) of the film formation chamber is reduced by reacting a flammable gas typified by monosilane with oxygen. After that, the supply of a monosilane gas and a hydrogen gas through the first and third gas supply means is stopped to supply only an argon gas into the film formation chamber. At this time, the argon gas flow rate is set to from 50 to 1000 sccm, preferably, from 50 to 200 sccm. In order to set the pressure of the film formation chamber approximately from 0.3 to 2 Torr (39.9 to 266 Pa), the turbo pump 121 or the rotary pump 122 is controlled.

[0032]

The distance between the substrate 140 and the target 104 including silicon (Si) is adjusted appropriately by using the target lifting means 107. Alternatively, the substrate may be carried up and down by using the substrate holding means 103.

[0033]

In this state, the high frequency power supply 106 is operated to apply high frequency to the target. Further, the target is applied with magnetic field by using the permanent magnet 104 that can move under the target. Thus, a semiconductor film that serves as a gettering sink is formed over the substrate. It is noted that the treatment time is set to 1 to 20 minutes, preferably approximately 5 minutes in this embodiment mode, although it should be set in view of deposition conditions or throughput.

[0034]

Moreover, the substrate may be applied with magnetic field by using the

magnetic material (magnet) 102. Preferably, a heated argon gas is supplied from above the substrate in order to spray it the surface to be deposited and the opposite side (a face not to be deposited) of the substrate. The flow rate of the heated argon gas may be set approximately 10 to 50 sccm.

5 [0035]

In the film formation chamber in which the pretreatment is preformed, a semiconductor film to serve as a gettering sink that is formed by sputtering has a nitrogen concentration of 1×10^{18} atoms/cm³ or lower, an oxygen concentration of 8×10^{19} atoms/cm³ or lower, and a noble gas concentration of 1×10^{20} atoms/cm³ or higher. 10 The thus obtained semiconductor film is suitable for a gettering sink, because it is not easily crystallized during the gettering process.

[0036]

The gettering sink of the present invention formed according to the above-described method is heated to perform gettering on an metal element within a semiconductor film that becomes a TFT active layer, and therefore, the etch residue can 15 be reduced when the semiconductor film that serves as a gettering sink is removed.

[0037]

(Embodiment Mode 2)

In this embodiment mode, an example of forming a semiconductor film that serves as a gettering sink by a method different from that of Embodiment Mode 1 is 20 described with reference to Fig. 2.

[0038]

Fig. 2 shows a sputtering apparatus for forming a semiconductor film that serves as a gettering sink. The sputtering apparatus shown in Fig. 2 is different in that

an electrode 150 including Ti is disposed in a film formation chamber 100 and a voltage is applied by an electrode power supply 151 to generate plasma in the interelectrode. The electrode 150 has a structure in which a target 105 is disposed between the electrodes and is perpendicular to the target.

5 [0039]

Next, a method for forming a semiconductor film that serves as a gettering sink by using the sputtering apparatus shown in Fig. 2 is described below.

[0040]

10 A substrate is held in a substrate holder 101, and then the substrate 140 is installed in a substrate holding means 103. In this embodiment mode, a case where a pretreatment is performed while the substrate is set in the substrate holding means 103 is described. However, the arrangement of the substrate is not limited to this.

[0041]

15 As the pretreatment in a film formation chamber, a voltage is applied to the electrode 150 from the electrode power supply 151. Plasma is generated in the interelectrode and thus, a titanium radical is generated. The titanium radical is reacted with oxygen in the film formation chamber, and then, is exhausted together with the oxygen through an exhausting means, thereby reducing the oxygen concentration of the film formation chamber. At this time, the pressure of the film formation chamber may
20 be set to approximately 10^{-4} Pa.

[0042]

A pretreatment for forming a semiconductor film that serves as a gettering sink is performed in this state for about 5 to 10 minutes. As a result, the oxygen concentration of the film formation chamber can be reduced. Alternatively, in the case

where the pretreatment is performed in a state in which the substrate is set in the substrate holding means 103, it is preferable that the substrate be heated at approximately 150 °C.

[0043]

5 A voltage is applied to the electrode including Ti to generate plasma and the impurity concentration of the film formation chamber is reduced due to the reaction with oxygen. After that, a noble gas element is supplied to the film formation chamber through a first gas supply means 130. Note that, in this embodiment mode, an argon gas is used as the noble gas element. At this time, the argon gas flow rate is set to
10 from 10 to 100 sccm, and the pressure of the film formation chamber is set to from 0.2 to 0.9 Pa, preferably, about 0.3 Pa.

[0044]

A target lifting means 107 is used to control the distance between the substrate 140 and the target 104 including Si appropriately. In addition, the substrate may be
15 carried up and down by using the substrate holding means 103.

[0045]

In this state, a high frequency power supply 106 is operated to apply high frequency power to the target. Further, the target is applied with magnetic field by using a permanent magnet 105 that can move under the target. It is noted that, in this
20 embodiment mode, electric power applied to the target (12 inch) is set to from 0.5 to 3 Kw, and preferably, the substrate 140 is heated at temperatures from 25 (the room temperature) to 300 °C. Thus, a semiconductor film that serves as a gettering sink is formed over the substrate. It is noted that the treatment time is set to 1 to 20 minutes, preferably approximately 5 minutes in this embodiment mode, although it should be set

in view of deposition conditions or throughput.

[0046]

Moreover, the substrate may be applied with magnetic field by using a magnetic material (magnet) 102. Preferably, a heated argon gas is supplied from above the substrate in order to spray the surface to be deposited and the opposite side (a face not to be deposited) of the substrate. The flow rate of the heated argon gas is set to approximately 10 to 50 sccm.

[0047]

In place of the electrode including Ti shown in Fig. 2, a filament 160 including Ti may be disposed as shown in Fig. 3. Preferably, the filament 160 is controlled to be heated by a filament power supply 161 only during the pretreatment. Specifically, a box-like wall 162 is arranged to surround the filament 160 as shown in Fig. 3. A lid of the wall having a box-like shape is controlled to be open during the pretreatment, whereas the lid is controlled to be closed during sputtering.

[0048]

In Fig. 3, the filaments are disposed symmetrically across the target. However, the number of the filament may be one, or three or more. In any case, the number of the filament is set as appropriate.

[0049]

A method for forming a semiconductor film that serves as a gettering sink by using the sputtering apparatus shown in Fig. 3 is the same as that in the case of disposing an electrode including Ti shown in Fig. 2. Therefore, a description thereof is omitted here.

[0050]

The semiconductor film to serve as a gettering sink that is formed in the film formation chamber in which the pretreatment is preformed has a nitrogen concentration of 1×10^{18} atoms/cm³ or lower, and an oxygen concentration of 8×10^{19} atoms/cm³ or lower. Further, the semiconductor film has a noble gas concentration of 1×10^{20} atoms/cm³ or higher. The thus obtained semiconductor film is suitable for a gettering sink, because it is not easily crystallized during the gettering process.

[0051]

The gettering sink of the present invention formed according to the above described method is heated to perform gettering on an metal element within a semiconductor film that becomes a TFT active layer, and therefore, the etch residue can be reduced when the semiconductor film that serves as a gettering sink is removed.

[0052]

(Embodiment Mode 3)

In this embodiment mode, a method for fabricating an active matrix substrate having a TFT formed by gettering using a gettering sink according to the present invention is described. In addition, multiple TFTs are formed over the active matrix substrate. Here, a driver circuit portion having an n-channel TFT and a p-channel TFT and a pixel portion having an n-channel TFT are described.

[0053]

As shown in Fig. 4(A), a base insulating film having a laminated structure of insulating films such as a silicon oxide film, a silicon nitride film, or a silicon oxynitride film is formed over a substrate 401 having an insulating surface (hereinafter, referred to as an insulating substrate). In this embodiment mode, a two-layer structure is

employed as the base insulating film. However, a single layer or two- or more-layer stack structure of the insulating films may be employed. As a first layer 402a of the base insulating film, a silicon oxynitride film is formed to be 10 to 200 nm in thickness (preferably, 50 to 100nm) is formed by using SiH₄, NH₃, N₂O and H₂ as reaction gases by a plasma CVD method. Here, the silicon oxynitride film is formed to have a thickness of 50nm. Then, as a second layer 402b of the base insulating film, a silicon oxynitride film is formed to be 50 to 200 nm in thickness (preferably, 100 to 150nm) is formed by using SiH₄ and N₂O as reaction gases by plasma CVD method. Here, the silicon oxynitride film is formed to have a thickness of 100 nm. The base film is provided for the sake of preventing alkaline metal included in the insulating substrate from diffusing into the semiconductor film.

[0054]

Subsequently, a first semiconductor film 403 is formed over the base film. As the first semiconductor film, a semiconductor film having an amorphous structure may be formed by a well-known method (a sputtering method, a LPCVD method, or a plasma CVD method). In this embodiment mode, the first semiconductor film is formed to be 10 to 100 nm in thickness using a semiconductor material including silicon as a main component by plasma CVD method. To obtain a better crystal structure, the impurity concentrations of oxygen, nitrogen or the like of the first semiconductor film may be reduced to 5×10^{18} atoms/cm³ or lower. For these reasons, a high purity material gas (a source gas) is used, and an ultra high vacuum CVD apparatus equipped with a mirror polishing (electrolytic polishing) reaction chamber in the inner wall of a film formation chamber or an oil-free vacuum pumping system may be used.

[0055]

A substance (including a film-form or in a liquid condition) having a metal element typified by Ni is formed over the first semiconductor film by any one method of a spin coating, a dip coating method, a plasma CVD method, a sputtering method, and a vapor deposition method. In this embodiment mode, Ni is used and a metal element containing film 404 is formed by spin-coating of a nickel acetate salt solution containing nickel of 1 to 100 ppm in weight. In this case, in order to enhance wettability of the first semiconductor film and the nickel acetate salt solution, preferably, an extremely thin oxide film is formed by using an ozone containing aqueous solution. Further, the extremely thin oxide film is removed once, and then, an extremely thin oxide film is formed by an ozone containing aqueous solution again. A film of the solution containing a metal element can be formed evenly over the first semiconductor film by forming the thin oxide film in this manner.

[0056]

Then, in this state, a heat treatment for crystallizing the first semiconductor film is performed to form a crystalline semiconductor film (a crystalline silicon film in this embodiment mode). As a method of a heat treatment, a furnace annealing method performed by using an electric heating furnace, a lamp rapid thermal anneal method (LRTA) performed by using a halogen lamp, a metal halide lamp, a xenon arc lamp, a carbon arc lamp, a high pressure sodium lamp, a high pressure mercury lamp or the like may be employed. Alternatively, a gas rapid thermal anneal method (GRTA) may be employed.

[0057]

Furthermore, in order to enhance crystallinity of the first semiconductor film

and repair defects left within crystal grains, the first semiconductor film may be irradiated with a laser beam. A continuous wave or pulsed type of gas laser or solid state laser can be used as the laser. An excimer laser, an Ar laser, a Kr laser and the like are given as the gas laser, while a YAG laser, a YVO₄ laser, a YLF laser, a YAlO₃ laser, a glass laser, a ruby laser, an Alexandrite laser, a Ti: Sapphire laser and the like are given as the solid state laser.

[0058]

When the first semiconductor film is crystallized, it is preferable that the solid state laser which is capable of oscillating continuously is used and the second harmonic through the fourth harmonic of the basic wave is applied in order to obtain crystals in large grain size. Typically, it is preferable that the second harmonic (with a thickness of 532 nm) or the third harmonic (with a thickness of 355 nm) of an Nd: YVO₄ laser (basic wave of 1064 nm) is applied.

[0059]

In this embodiment mode, a laser beam emitted from the continuous wave type YVO₄ laser with 10 W output is converted into a harmonic by using a non-linear optical element. Also, a method of emitting a harmonic by applying crystals of YVO₄ and the non-linear optical element into a resonator can be given. Then, preferably, the laser beam is shaped into a rectangular shape or an elliptical shape in the irradiation face by an optical system, thereby irradiating the first semiconductor film. At this time, the energy density of approximately 0.01 to 100 MW/cm² (preferably 0.1 to 10 MW/cm²) is required. The first semiconductor film and the laser beam are moved relatively at approximately 0.5 to 2000 cm/s rate.

[0060]

A metal element (Ni in this embodiment mode) is left in the crystalline semiconductor film formed as described above. The concentration of the metal element within the first semiconductor film is reduced by gettering that is described
5 below.

[0061]

An insulating film that serves as a barrier film is formed over the first semiconductor film that is crystallized. The barrier film may be treated by using ozone water, or a solution in which sulfuric acid, hydrochloric acid, or nitric acid is mixed
10 with hydrogen peroxide solution to form an oxide film (a chemical oxide). As other methods, plasma treatment in oxidization atmosphere or ultraviolet irradiation in oxygen-containing atmosphere may be adopted to form an oxide film, or an insulating film including a silicon oxide film may be formed by a plasma CVD method, a sputtering method, or a vapor-deposition method.

15 [0062]

As shown in Fig. 4(B), a second semiconductor film 405 that serves as a gettering sink is formed to be 25 to 250 nm thick over the barrier film. At this time, a pretreatment is performed in the film formation chamber as described in Embodiment Mode 1 or 2, and then the second semiconductor film including a silicon mainly is
20 formed by a sputtering method. The second semiconductor film has a nitrogen concentration of 1×10^{18} atoms/cm³ or lower, an oxygen concentration of 8×10^{19} atoms/cm³ or lower, and a noble gas concentration of 1×10^{20} atoms/cm³ or higher.

[0063]

Preferably, the second semiconductor film is a low density film, since the

second semiconductor film is to be removed in the later process. For example, a semiconductor film having a low density can be formed by allowing the second semiconductor film to contain 25 to 40 atom % of hydrogen.

[0064]

5 After that, Ni, which is a metal element within the first crystalline semiconductor film, is diffused and moved into the second semiconductor film that serves as a gettering sink by performing a heat treatment to perform a gettering treatment. The heat treatment may be performed by a furnace annealing method, a LRTA method or a GRTA method. When the furnace annealing method is employed,
10 the heat treatment is performed for 0.5 to 12 hours at temperatures from 450 to 600 °C in a nitrogen atmosphere. Also, when the LRTA method is employed, a lamp light source for heating is kept on for 1 to 60 seconds, preferably for 30 to 60 seconds, and it is repeated from 1 time to 10 times, preferably from 2 times to 6 times. Luminescence intensity of the lamp light source may be set on arbitrary bases. Also, it is set so that
15 the semiconductor film may be heated at temperatures from 600 to 1000 °C momentarily, and heated at as high as about 700 to 750 °C preferably.

[0065]

In addition, the heat treatment for gettering may be performed to crystallize the first semiconductor film. That is, it is possible to achieve a gettering and crystallize
20 the first semiconductor film by performing one time heat treatment, thereby reducing the number of processes.

[0066]

After that, the second semiconductor film 406 is removed by wet etching. As etching methods, wet etching by an alkali solution such as a solution containing

hydrazine or tetraethyl ammonium hydroxide (TMAH) can be adopted. At this time, the barrier layer functions as an etching stopper. Also, the barrier layer may be removed by hydrofluoric acid, after the second semiconductor is etched.

[0067]

5 The thus formed crystalline semiconductor film has crystals with an elongated stick or elongated flat shape due to an action of the metal element and each crystal has grown with a specific directionality when seen in broad perspective.

[0068]

10 Then, boron is added into the crystalline semiconductor film (referred to as a channel doping). Thereafter, as shown in Fig. 4(C), it is patterned to have a desired shape as an active layer (406a to 406d).

[0069]

15 Subsequently, the surface of the active layer is washed with an etchant including hydrofluoric acid and then a gate insulating film 407 for covering the active layer is formed. The gate insulating film 407 is formed from an insulating film including silicon to be 40 to 150 nm thick by a plasma CVD method or a sputtering method. In this embodiment, a silicon oxynitride film (composition ratio: Si=32%, O=59%, N=7%, H=2%) is formed with a thickness of 115 nm by a plasma CVD method. It is natural that the gate insulating film should not be limited to an oxynitride film. A
20 single layer or a stacked layer structure of another insulating film including silicon may be used.

[0070]

Next, as shown in Fig. 4(D), over the gate insulating film, a first conductive film 411 with a thickness of 20 to 100 nm and a second conductive film 412 with a

thickness of 100 to 400 nm are formed in lamination to form a gate electrode. In this embodiment mode, a 50 nm thick tantalum nitride film and a 370 nm thick tungsten film are sequentially laminated over the gate insulating film 407 to form the gate electrode.

5 [0071]

As the first conductive film and the second conductive film, an element selected from the group consisting of Ta, W, Ti, Mo, Al and Cu, or an alloy material or a compound material containing any one of the above-described elements as its main component may be employed. Further, a semiconductor film typified by a polycrystalline silicon film doped with an impurity element such as phosphorus, or an AgPdCu alloy may be used as the first conductive film and the second conductive film. Further, it is not limited to a two-layer structure. For example, a three-layer structure may be adopted in which a 50 nm thick tungsten film, an alloy film of aluminum and silicon (Al-Si) with a thickness of 500 nm, and a 30 nm thick titanium nitride film are sequentially laminated. Moreover, in the case of a three-layer structure, tungsten nitride may be used in place of tungsten for the first conductive film, an alloy film of aluminum and titanium (Al-Ti) may be used in place of the alloy film of aluminum and silicon (Al-Si) for the second conductive film, and a titanium film may be used in place of the titanium nitride film for the third conductive film. Alternatively, a single layer structure may also be adopted. The TaN film is used for the first conductive film and the W film for the second conductive film in this embodiment mode.

[0072]

Then, gate electrodes and wirings are each formed by patterning according to the procedures described below. The first and second conductive films can be etched

to have a desired tapered shape by using ICP (inductively coupled plasma) etching method and suitably adjusting the etching conditions (the amount of power applied to a coiled electrode, the amount of power applied to an electrode on the substrate side, the temperature of the electrode on the substrate side, etc.). An etching gas can be chosen
5 appropriately from a chlorine-based gas typified by Cl_2 , BCl_3 , SiCl_4 , or CCl_4 , a fluorine-based gas typified by, CF_4 , SF_6 , or NF_3 , or O_2 .

[0073]

A resist having a desired shape is formed over the second conductive film. As the first etching condition, CF_4 , Cl_2 , and O_2 are used as etching gases, the flow rate ratio
10 of the gases is set to 25/25/10 sccm, and, at a pressure of 1 Pa, RF (13.56 MHz) power of 700 W is applied also to the coiled electrode and RF (13.56 MHz) power of 150 W is applied also to the substrate side (sample stage) to substantially apply a negative self-bias voltage. The area of the electrode on the substrate side is $12.5 \text{ cm} \times 12.5 \text{ cm}$, and the area of the coiled electrode (here, quartz disc provided with coil) is a 25 cm
15 diameter disc. The W film as the second conductive film only is etched so as to allow end portions thereof to have a tapered shape having an angle of from 15 to 45 ° in this etching condition.

[0074]

Then, second etching is performed without removing a mask made of resist
20 (hereinafter, a resist mask). As the second etching condition, CF_4 and Cl_2 are used as etching gases, the flow rate ratio of the gases is set to 30/30 sccm, and RF (13.56 MHz) power of 500 W is applied to the coiled electrode at a pressure of 1 Pa and RF (13.56 MHz) power of 20 W is also applied to the substrate side (sample stage) to substantially apply a negative self-bias voltage. Under the second etching condition, both the TaN

film as the first conductive film and the W film as the second conductive film are etched to the same degree.

[0075]

Next, a first doping treatment for adding an impurity element that gives a semiconductor film a conductivity type is performed by using the gate electrode as a mask without removing the mask made of resist. For the first doping treatment, ion doping or ion implantation may be employed. As an impurity element that gives n-type, phosphorus (P) or arsenic (As) is typically used. First impurity regions (n+ region) 408a to 408d are formed in a self-aligned manner. The first impurity regions are added with the impurity elements that give n-type at the concentration ranging from 1×10^{20} to $1 \times 10^{21}/\text{cm}^3$.

[0076]

Then, third etching is performed without removing the resist mask. Here, as a condition for the third etching, CF_4 and Cl_2 are used as etching gases, the flow ratio of the gases is set to 30/30 sccm, and RF (13.56 MHz) power of 500 W is applied to the coiled electrode at a pressure of 1 Pa and RF (13.56 MHz) power of 20 W is also applied to the substrate side (sample stage) to substantially apply a negative self-bias voltage.

[0077]

Fourth etching is performed without removing the resist mask. Here, as the fourth etching condition, CF_4 , Cl_2 , and O_2 are used as etching gases, the flow ratio of the gases is set to 20/20/20 sccm, and, at a pressure of 1 Pa, RF (13.56 MHz) power of 500 W is applied also to the coiled electrode and RF (13.56 MHz) power of 20 W is applied also to the substrate side (sample stage) to substantially apply a negative self-bias

voltage. Under the conditions for the third and fourth etching, the W film and the TaN films are anisotropically etched. By allowing the etching gas to contain oxygen, the W film and the TaN film become different from each other in the etching speeds, and thus, the etching speed of the W film is higher than that of the TaN film. Although not shown in figures, the gate insulating film that is not covered with the first conductive film is etched to be thinner. At this time, the gate electrodes and the like are formed, in which 411a to 411d of the TaN film as the first conductive layer become lower layers and 412a to 412d of the W film as the second conductive layer become upper layers.

[0078]

Next, second doping is conducted without removing the resist mask to add an impurity element for imparting a conductivity type to the semiconductor film by using the gate electrodes as masks. The second doping may be conducted by an ion doping method or an ion implantation method. In this embodiment mode, the ion doping method is used. A flow rate of a gas in which phosphine (PH_3) is diluted with hydrogen at 5 % is set to 30 sccm, a dose is set to 1.5×10^{14} atoms/cm², and an accelerating voltage is set to 90 keV. The resist mask and the second conductive layer become masks. Through the second doping, second impurity regions 409a to 409d which are overlapped with the gate electrodes are formed.

[0079]

Subsequently, the mask made of resist is removed, and then a new mask made of resist is formed to perform third doping. Through the third doping, the third impurity regions 408a and 408d that are given an impurity element (such as boron) for imparting p-conductivity type to a semiconductor film forming a p-channel TFT, and fourth impurity regions 409a and 409d that are overlapped with each gate electrode are

formed. The third impurity regions 408a, 408d are to be added with the impurity element for imparting the p-type at a concentration range of $1 \times 10^{20} / \text{cm}^3$ to $1 \times 10^{21} / \text{cm}^3$. Note that the third impurity regions are the regions (n+ region) to which phosphorus (P) is added in the preceding step. However, because the concentration of the impurity element for imparting the p-type, which is added, is 1.5 times to 3 times higher, the conductivity type becomes the p-type. The fourth impurity regions 409a and 409d are also the regions to which phosphorus (P) is added in the preceding step. However, because the concentration of the impurity element for imparting the p-type, which is added, is 1.5 times to 3 times higher, the conductivity type becomes the p-type.

[0080]

According to the above processes, the impurity regions each having the conductivity type of the n-type or the p-type are formed in the respective semiconductor films. After the formation of the impurity regions, a heat treatment, intense light irradiation, or laser light irradiation is conducted in order to activate the impurity element. At the same time as the activation, plasma damage to the gate insulating film and plasma damage to an interface between the gate insulating film and the semiconductor layers can be recovered. In particular, the impurity element is activated by using an excimer laser from the front surface or the rear surface in an atmosphere of temperatures from a room temperature to 300°C . The irradiation of a second harmonic of the YAG laser may be conducted for activation. A YAG laser is a preferable activation unit because of easy maintenance.

[0081]

Next, as shown in Fig. 4(E), a passivation film 415 made of an insulating film such as a silicon oxynitride film or a silicon oxide film is formed. In this embodiment

mode, a silicon oxynitride film is formed to have a thickness of 100 nm by a plasma CVD method. After that, heating is conducted at temperatures from 300°C to 550°C for 1 hour to 12 hours using a clean oven to hydrogenate the semiconductor film. In this embodiment mode, heating is conducted in a nitrogen atmosphere at 410°C for 1 hour. According to this step, dangling bonds in the semiconductor layer can be terminated by hydrogen contained in the first passivation film 415. At the same time, the above-mentioned activation processing of the impurity regions can be conducted in addition to the hydrogenation.

[0082]

After that, as shown in Fig. 4(F), a first interlayer insulating film 416 made of an inorganic insulating film including silicon or an organic insulator material is formed over the passivation film. A positive type photosensitive organic resin or a negative type photosensitive organic resin can be used as the organic insulator material. Note that, in the case where the photosensitive organic resin is used for the first interlayer insulating film, the photosensitive organic resin is etched by an exposure treatment in a photolithography process, thereby forming a first opening portion having a curvature. When the positive type photosensitive organic resin is used for the first interlayer insulating film, it is necessary to decolorize the photosensitive organic resin after etching, since the positive type photosensitive organic resin is colored brown. In this embodiment mode, a silicon oxide film having a thickness of 1.5 μm is formed as a first interlayer insulating film by plasma CVD method.

[0083]

After that, a second passivation film 417 made of a nitride insulating film (typically, a silicon nitride film or a silicon nitride oxide film) is formed to cover the

first interlayer insulating film 416. In this embodiment mode, a silicon nitride film is used for the second passivation film. With respect to film formation conditions, a silicon target may be used by a sputtering method using high frequency discharge, and a nitrogen gas may be used as a sputtering gas. A pressure may be set as appropriate within 0.5 Pa to 1.0 Pa. Discharge power may be within 2.5 kW to 3.5 kW. A film formation temperature may be at temperatures from a room temperature (25°C) to 250°C. When the second passivation film 417 made from the nitride insulating film is formed, degassing produced from the first interlayer insulating film 416 can be suppressed.

[0084]

Next, the second passivation film 417, the first interlayer insulating film 416, the first passivation film 415, and the gate insulating film 407 are etched in order, thereby forming opening portions. At this time, etching treatment may be dry etching treatment or wet etching treatment. In this embodiment mode, the opening portions having smooth taper (angle) are formed by dry-etching. After forming the opening portions, a metal film is formed over the second passivation film and the opening portions, and then, the metal film is etched to form a source/drain electrode 418, wirings (not shown). A film comprising an element selected from the group consisting of aluminum (Al), titanium (Ti), molybdenum (Mo), tungsten (W), and silicon (Si) or an alloy film made from those elements may be used as the metal film. In this embodiment mode, a titanium film (Ti), a silicon-aluminum alloy film (Al-Si), and a titanium film (Ti) are laminated to be 100 nm, 350 nm, and 100 nm in thickness, respectively, and then shaped into a desired shape by patterning and etching, thereby forming a source/drain electrode and wirings (not shown). After that, a pixel electrode

420 (which becomes an anode or a cathode in a light emitting device) is formed. A transparent conductive film of ITO, SnO₂, or the like can be used for the electrode 420. In this embodiment mode, an ITO film is formed to have a thickness of 110 nm and etched to have a desired shape, thereby forming the electrode 420.

5 [0085]

According to the above-mentioned process, an active matrix substrate including TFTs is completed.

[0086]

10 In the present invention, a semiconductor film in which nitrogen concentration is 1×10^{18} atoms/cm³ or lower, oxygen concentration is 8×10^{19} atoms/cm³ or lower, and noble gas concentration is 1×10^{20} atoms/cm³ or higher is formed. Etch residue in the semiconductor film can be reduced by gettering. An active matrix substrate which has a good crystalline semiconductor film and includes TFTs having good device properties can be provided.

15 [0087]

In this embodiment mode, although a TFT having a top-gate structure is described, a TFT having a bottom-gate structure may be employed.

[0088]

(Embodiment Mode 4)

20 In this embodiment mode, being different from Embodiment Mode 3, a method for manufacturing an active matrix substrate formed over a quartz substrate that is resistant to a relatively high temperature is described. Here, like Embodiment Mode 3, a driver circuit portion including an n-channel TFT and a p-channel TFT, and a pixel portion including an n-channel TFT are described. Note that, semiconductor films and

respective electrodes may be formed of materials selected from the materials described in Embodiment Mode 1.

[0089]

First, as shown in Fig. 5(A), an amorphous silicon film 502 is formed over a quartz substrate 501 as a first semiconductor film. Because an impurity such as alkali metal that adversely affects operations of TFTs is not mixed in a quartz substrate, a base film that prevents it is not necessarily provided. Then, the amorphous silicon film is formed over the quartz substrate 501 by any one of the methods described in Embodiment Mode 3. Then, a metal element is formed so that it can be contact with the amorphous silicon film by any one of the methods described in Embodiment Mode 3. Thereafter, a gas such as hydrogen or the like is expelled from the amorphous silicon film by heat treatment for one hour at the temperature 450 °C. A crystalline semiconductor film (a crystalline silicon film in this embodiment mode) is formed by heat treatment for eight hours at the temperature of 600 °C. Irradiation of a laser beam may be performed as shown in Embodiment Mode 3 for the sake of promoting the crystallinity as necessary.

[0090]

Subsequently, an insulating film to be a barrier film is formed over the first semiconductor film that was crystallized, as shown in Embodiment Mode 3. A second semiconductor film that serves as a gettering sink is formed to be 25 to 250 nm thick over the barrier film. At this time, a pretreatment is performed in the film formation chamber as described in Embodiment Mode 1 or 2, and then, the second semiconductor film including silicon mainly is formed by a sputtering method. The second semiconductor film has nitrogen concentration of 1×10^{18} atoms/cm³ or lower, oxygen

concentration of 8×10^{19} atoms/cm³ or lower, and noble gas concentration of 1×10^{20} atoms/cm³ or higher. Preferably, the second semiconductor film is a low density film, since the second semiconductor film is to be removed in the later process. For example, a semiconductor film having a low density can be formed by allowing the
5 second semiconductor film to contain 25 to 40 atom % of hydrogen.

[0091]

After that, Ni that is a metal element within the first crystalline semiconductor film is diffused and moved into the second semiconductor film that serves as a gettering sink by performing heat treatment for gettering, according to any method shown in
10 Embodiment Mode 3. In addition, the heat treatment for gettering may be performed also to crystallize the first semiconductor film. That is, it is possible to perform a gettering and crystallize the first semiconductor film by performing one time heat treatment, thereby reducing the number of processes.

[0092]

15 After that, the second semiconductor film is removed by wet etching. As the etching method, the method that is described in Embodiment Mode 3 may be adopted. At this time, the barrier layer functions as an etching stopper. After that, the barrier layer may be removed by hydrofluoric acid.

[0093]

20 The thus formed crystalline semiconductor film has crystals with an elongated stick or elongated flat shape due to an action of the metal element and each crystal has grown with a specific directionality when seen in broad perspective.

[0094]

Next, the crystalline silicon film is patterned into a desired shape and a gate

insulating film 503 is formed by thermal oxidation. Then, boron is added to the crystalline silicon film (channel doping). After that, as shown in Fig. 5(B), gate electrodes are formed over the gate insulating film. In this embodiment mode, the gate electrodes comprise a laminate of a tantalum nitride (TaN) 504 and a tantalum 505.

5 [0095]

Then, a mask of a silicon oxide film is formed, opening portions are formed over impurity regions, and an impurity element such as phosphorus or boron is added, thereby forming a source/drain region. Note that, as for a method of forming the source/drain region, Embodiment Mode 3 may be referred to, and low concentration
10 impurity regions overlapped with the gate electrode may be provided as appropriate.

[0096]

After that, activation of the impurity regions is conducted in a nitrogen atmosphere at 800°C for one hour. In this embodiment mode, the activation can be conducted at a high temperature of 800°C because the quartz substrate is used.

15 [0097]

Next, as shown in Fig. 5(C), a passivation film 506 of silicon nitride is formed and hydrogenation of the semiconductor films is conducted. Then, as shown in Fig. 5(D), a first interlayer insulating film 507 is formed over the passivation film and an insulating film 508 including nitrogen is formed thereover. An acrylic resin material is
20 applied to the whole surface of the passivation film and then, over the film, a silicon nitride film is formed by sputtering. After that, a resist mask having a predetermined shape is formed, the first interlayer insulating film and the silicon nitride film are etched by dry-etching to form a contact having a tapered shape over the source/drain region. The tapered shape of the contact can also have a curvature radius depending on a

material for an interlayer insulating film or a condition for exposure.

[0098]

As shown in Fig. 5(E), source/drain wirings 509, in which a titanium (Ti) film, an aluminum-silicon alloy (Al-Si) film, and a titanium (Ti) film are laminated, are formed in the opening portions. Then, a second interlayer insulating film 510 is formed of an organic resin material and an electrode 511 (which becomes an anode or a cathode of an EL display device, or becomes a pixel electrode of a liquid crystal display device) is formed via a contact formed in the interlayer insulating film.

[0099]

The interlayer insulating film described in Embodiment Modes 1 and 2 or an insulating film including nitrogen can be used in the process of Embodiment Mode 3.

[0100]

According to the above-mentioned process, an active matrix substrate including TFTs is completed.

[0101]

According to the present invention, even in the process of using a quartz substrate, a semiconductor film that serves as a gettering sink in which nitrogen concentration is 1×10^{18} atoms/cm³ or lower, oxygen concentration is 8×10^{19} atoms/cm³ or lower, and further, noble gas concentration is 1×10^{20} atoms/cm³ or higher can be formed. Etch residue can be reduced by performing the gettering using the semiconductor film. An active matrix substrate having a good crystalline semiconductor film and including TFTs having good device properties can be provided.

[0102]

In this embodiment mode, although a TFT having a top-gate structure is

described, a TFT having a bottom-gate structure may be employed.

[0103]

(Embodiment Mode 5)

This embodiment mode describes an example, with reference to Fig. 6, of forming a EL display device (EL display module) in which a light emitting element is provided for an active matrix substrate which is formed according to the method described in Embodiment Mode 3 or 4.

[0104]

First, when the electrode 420 or 511 as described in Embodiment Mode 3 or 4 becomes an anode of the EL display device, the electrode is made of a metal (Pt, Cr, W, Ni, Zn, Sn, or In) having a large work function. In this embodiment mode, the electrode is formed of ITO having a large work function and etched to have a desired shape.

[0105]

Next, as shown in Fig. 6(A), an insulator 601 (which is called a bank, an isolation wall, a partition wall, a mound, or the like) covering edge portions of the electrode 420 or 511 is formed. The insulator 601 may be made of a photosensitive organic resin. For example, when a negative type photosensitive acrylic resin is used as a material of the insulator, the insulator 601 having a curved surface having a first curvature radius in an upper end portion thereof and a curved surface having a second curvature radius in a lower end portion thereof can be formed. Preferably, the first curvature radius and the second curvature radius are set to from 0.2 μm to 3 μm . In addition, the insulator 601 may be covered with a second protective film made of an aluminum nitride film, an aluminum nitride oxide film, or a silicon nitride film. In this

embodiment mode, a positive type photosensitive acrylic resin is used to form the insulator 601.

[0106]

After that, contaminants and the like are removed by wiping using a PVA (polyvinyl alcohol) base porous material. In this embodiment mode, dusts (contaminants) generated when the ITO film or the insulating film is etched can be removed by wiping using bellclean.

[0107]

Next, in a pretreatment before vapor deposition of a light emitting layer (layer containing organic compounds), PEDOT may be applied onto the entire surface and then, baking may be conducted. At this time, preferably, once the PEDOT is applied, then washing is conducted and the PEDOT is applied again because the PEDOT has low wettability with ITO. After that, heating is conducted in a low pressure atmosphere. In this embodiment mode, after the application of the PEDOT, heating is conducted at the temperature of 170°C for 30 minutes in a low pressure atmosphere, followed by natural cooling for 30 minutes.

[0108]

Then, by using a vapor deposition apparatus, vapor deposition is conducted while a vapor deposition source is being moved. For example, vapor deposition is conducted in a film formation chamber whose air is evacuated up to the degree of vacuum of 5×10^{-3} Torr (0.665 Pa) or lower, preferably, 10^{-4} Torr to 10^{-6} Torr. In the vapor deposition, the organic compounds are vaporized in advance by resistance heating. During the vapor deposition, a shutter is opened, so that the vaporized organic compounds are scattered toward the substrate. The vaporized organic compounds are

scattered upward and vapor-deposited onto the substrate through opening portions provided in a metal mask, thereby forming a light emitting layer 602 (including a hole transporting layer, a hole injecting layer, an electron transporting layer, and an electron injecting layer).

5 [0109]

Next, a second electrode 603 is formed as a cathode over the above-mentioned light emitting layer. The second electrode 603 may be made of a thin film containing metal (Li, Mg, or Cs) having a small work function. In addition, it is preferable that the second electrode be made from a laminate film in which a transparent conductive
10 film (ITO, alloy of indium oxide and tin oxide), alloy of indium oxide and zinc oxide ($\text{In}_2\text{O}_3\text{-ZnO}$), zinc oxide (ZnO), or the like) is laminated over the thin film containing Li, Mg, Cs, or the like. Further, in order to reduce a resistance of the cathode, an auxiliary electrode may be provided over the insulator 601.

[0110]

15 Here, the example in which the light emitting layer 602 is formed by a vapor deposition method is described. However, there are no particular limitations. A light emitting layer made of a polymer may be formed by an application method (such as spin coating method, inkjet method). In addition, in this embodiment mode, the example in which the layer made from a low molecular material is laminated as the
20 organic compound layer is described. However, a layer made of a polymer material and a layer made of a low molecular material may be laminated. In addition, RGB light emitting layers may be formed to achieve full color display, or in the case of forming a monochrome light emitting layer, full color display may be achieved by using a color conversion layer or a color filter.

[0111]

Note that, with respect to an EL display device, two structures are considered according to a light emitting direction. One is a structure in which light emitted from a light emitting element passes through the second electrode 603 and reaches the eyes of an observer. The other is a structure in which the light emitted from the light emitting element passes through the electrode 420 or 511 and through the substrate and reaches the eyes of the observer. When a structure in which light emitted from the light emitting device passes through a first electrode and reaches the eyes of the observer is used, it is desirable to use a light-transmitting material for the electrode 420 or 511.

[0112]

After forming up to the second electrode 603 according to the above-mentioned processes, the next steps are, as shown in the entire view of an EL display device in Fig. 6(B), as follows: a silicon nitride film is provided as a first protective film 604; a resin film made of a ultraviolet curable resin, an epoxy resin, or other resin is provided as a second protective film 605; and a plastic film is provided as a cover material 606 thereover. Note that, preferably, the surface of the plastic film is covered with an inorganic insulating film such as a silicon nitride film to prevent moisture and oxygen from passing through the film. After that, an FPC (flexible printed circuit) 612 is connected with an external terminal by using an anisotropic conductive film 611, thereby completing the EL display device (EL display module).

[0113]

Thus, according to the present invention, a semiconductor film that serves as a gettering sink in which nitrogen concentration is 1×10^{18} atoms/cm³ or lower, oxygen concentration is 8×10^{19} atoms/cm³ or lower, and noble gas concentration is 1×10^{20}

atoms/cm³ or higher can be formed. Therefore, etch residue in the semiconductor film can be reduced, and therefore, an EL display device having a higher yield can be manufactured.

[0114]

5 (Embodiment Mode 6)

In this embodiment mode, referring to Figs. 7A and 7B, an example is described in which a liquid crystal element is provided in the active matrix substrate formed in the way described in Embodiment Mode 3 or 4, thereby producing a liquid crystal display device (liquid crystal display module).

10 [0115]

First, the electrode 420 or 511 described in Embodiment Mode 3 or 4 is formed of ITO and the electrode is used as a pixel electrode of a transmissive liquid crystal display device. Note that, in the case of a reflection liquid crystal display device, the pixel electrode may be made of a metal film such as Al. After that, as shown in Fig. 7(A), a planarizing film 701 is made of an organic material. At this time, the planarizing film may be made of an inorganic material and flattened by CMP or the like.

[0116]

After that, an alignment film 702 is provided on the active matrix substrate. An opposite electrode 703 is provided in an opposite substrate 704 prepared in advance. As shown in Fig. 7(B), the opposite substrate and the active matrix substrate are bonded to each other by a sealant 708 and then a liquid crystal 707 is injected therebetween, thereby producing a liquid crystal cell. Note that the liquid crystal element is an element that controls light transmission or non-light transmission according to an optical modulation action of the liquid crystal. The liquid crystal device comprises a

pair of electrodes and the liquid crystal interposed therebetween. Further, an FPC (flexible printed circuit) 712 may be bonded by an anisotropic conductive film 711 to serve as an external terminal.

[0117]

5 Thus, according to the present invention, a semiconductor film that serves as a gettering sink in which nitrogen concentration is 1×10^{18} atoms/cm³ or lower, oxygen concentration is 8×10^{19} atoms/cm³ or lower, and noble gas concentration is 1×10^{20} atoms/cm³ or higher can be formed. Therefore, etch residue in the semiconductor film can be reduced, and therefore, a liquid crystal display device having a higher yield can
10 be manufactured.

[0118]

[Embodiment]

(Embodiment 1)

This embodiment describes outcomes of impurity concentration in a gettering
15 sink measured in both a case in which residue is generated in a gettering sink and a case in which residue is not generated in a gettering sink.

[0119]

An oxynitride (SiNO) film (50 nm) and a nitride oxide (SiON) film (100 nm) are laminated as a base film over a glass substrate. After that, an amorphous silicon
20 film (a first amorphous silicon film) is formed to be 50 nm thick over the base film, and 10 ppm solution containing a metal element Ni is applied. After that, it is heated in a furnace for one hour at the temperature of 500°C, and then, for four hours at the temperature of 550°C for crystallization of the amorphous silicon film. It is irradiated with a XeCl excimer laser, thereby reducing defects in grains and enhancing

crystallinity by enlarging grain size to form a first crystalline silicon film.

[0120]

Subsequently, a barrier film is formed over the first crystalline silicon film by applying ozone water using a washing machine. An amorphous silicon film (a second
5 amorphous silicon film) that is to function as a gettering sink is formed to be 50 nm by sputtering. At this time, a pressure of film formation is set 0.4 Pa, a substrate temperature is 150 °C, electric power of film formation is 3 Kw, the size of a target is 12 inches square, a film formation gas is Ar, the flow rate thereof is set 50 sccm, and further, 10 sccm heated Ar is supplied to the vicinity of the substrate.

10 [0121]

When the second amorphous silicon is formed, a pretreatment of the present invention is performed to reduce the impurity concentrations. As a result, the second amorphous silicon film in which nitrogen concentration is 1×10^{18} atoms/cm³ or lower, oxygen concentration is 8×10^{19} atoms/cm³ or lower, and Ar concentration is 1×10^{20}
15 atoms/cm³ or higher is obtained.

[0122]

A heat treatment is performed using a vertical furnace for four hours at the temperature of 550 °C so that Ni can be diffused into the second amorphous silicon film by gettering.

20 [0123]

After gettering is finished, in a constant temperature bath, TMAH is held in a quartz container at the temperature of 50 °C, and the second amorphous silicon film is removed by etching for approximately 3 minutes. In this case, as described in Embodiment Modes, the barrier film functions as an etching stopper, and thus, the first

crystalline silicon film is not etched. Thereafter, the barrier film is removed by a hydrofluoric acid treatment to obtain a crystalline silicon film having Ni concentration of 3×10^{16} atoms/cm³ or lower.

[0124]

5 Table 1 shows impurity concentrations of carbon, nitrogen, oxygen, and chlorine in the crystalline semiconductor film (a measured sample 1) formed as described above and a crystalline semiconductor film (a measured sample 2) formed according to a conventional method.

[0125]

10 [Table 1]

IMPURITY CONCENTRATION (atoms/cm ³)	CARBON	NITROGEN	OXYGEN	CHLORINE
MEASURED SAMPLE 1(PRESENT INVENTION)	2.00×10^{18}	4.00×10^{17}	3.00×10^{18}	3.00×10^{15}
MEASURED SAMPLE 2(CONVENTIONAL ART)	8.00×10^{19}	1.00×10^{19}	9.00×10^{19}	1.00×10^{17}

[0126]

As apparent from the table 1, the sample without having etching residue, formed according to the present invention, exhibits each low concentration of the
 15 impurities. That is, it can be known that impurity concentration (particularly, oxygen concentration or nitrogen concentration) is required to control in order to reduce etch residue.

[0127]

A cause of generating residue of a gettering sink due to the above impurity

elements is considered as follows: even if noble gas concentration in gettering sink is the same, oxygen becomes an extraction core to reduce a degree of solution of a metal element. Therefore, in the case of oxygen concentration in a gettering sink increase and an extraction nucleus exists due to the oxygen, it is difficult to dissolve residue when the gettering sink is removed by etching, and thus, the residue is generated.

[0128]

According to the present invention, a gettering sink can be removed precisely while keeping a predetermined gettering function, by controlling impurity concentration in the gettering sink, thereby enhancing a yield in TFT fabricating. When residue is not left, a gettering defect is not generated either. Therefore, fluctuation in electric characteristic of a TFT becomes smaller, and thus, the reliability becomes better.

[0129]

[Effect of the Invention]

According to the present invention, in a chamber in which a semiconductor film that serves as a gettering sink is formed, a pretreatment is performed to reduce impurity concentrations, thereby making nitrogen concentration set to 1×10^{18} atoms/cm³ or lower, oxygen concentration set to 8×10^{19} atoms/cm³ or lower in the semiconductor film serving as a gettering sink. Accordingly, etch residue in the semiconductor film can be reduced. Therefore, etch residue is reduced as compared with a method for manufacturing a TFT using a semiconductor film that serves as a gettering sink according to a conventional method. Therefore, it is possible to manufacture a display device having a TFT with a better yield.

[Brief Description of the Drawings]

[Fig. 1] A view showing a sputtering apparatus carrying out the present invention.

[Fig. 2] A view showing a sputtering apparatus carrying out the present invention.

[Fig. 3] A view showing a sputtering apparatus carrying out the present invention.

[Fig. 4] A view showing a method for fabricating an active matrix substrate using the present invention.

5 [Fig. 5] A view showing a method for fabricating an active matrix substrate using the present invention.

[Fig. 6] A view showing a method for manufacturing an EL display device using the present invention.

[Fig. 7] A view showing a method for manufacturing a liquid crystal display device
10 using the present invention.

[Document Name] Abstract

[Abstract]

[Object]

When a gettering sink is removed by using alkaline solution of etchant having a
5 high selectivity of the gettering sink to a barrier film functioning as an etching stopper,
residue of the gettering sink is left.

[Solving Means]

A characteristic is that a semiconductor film that serving as a gettering sink
contains a nitrogen concentration of 1×10^{18} atoms/cm³ or lower, an oxygen
10 concentration of 8×10^{19} atoms/cm³ or lower, and a noble gas concentration of 1×10^{20}
atoms/cm³ or higher. In order to achieve the above-described impurity concentrations,
the present invention is characterized in that a concentration of oxygen that is an
impurity element in a chamber is reduced by using a flammable gas for heating and
exhausting oxygen, for example.

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